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LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)

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Environmental Protection Department
Environmental Restoration Division

Table of Contents

3-96/ERD:rtd

Table of Contents (TOC) reflects the above-mentioned completed and revised SOPs. The remaining SOPs and a revised TOC will be forwarded to you for inclusion into the SOP manual.

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LLNL Environmental Restoration Division Standard Operating Procedure	TITLE: Field Borehole Logging
APPROVAL Date _____ _____ Livermore Site Deputy Program Leader	PREPARERS: R. Devany*, J. Gardner*, S. Gregory, J. Hoffman*, and S. Nelson* REVIEWERS: R. Bainer, L. Berg*, T. Carlsen, V. Dibley, and M. Dresen*
APPROVAL Date _____ _____ Division Leader CONCURRENCE Date _____ _____ QA Implementation Coordinator	PROCEDURE NUMBER: ERD SOP-1.1 REVISION: 2 EFFECTIVE DATE: December 1, 1995 Page 1 of 32

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1.0 PURPOSE

To describe the physical characteristics of sediments and rock encountered during auger, rotary, punch core or core drilling and to document the procedures used during geophysical logging and the collection of subsurface samples for chemical analysis.

2.0 APPLICABILITY

The following procedures should be reviewed and followed by all personnel performing any borehole logging activities.

3.0 REFERENCES

3.1 American Society for Testing and Materials (1991), *Standard Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D:1586-84, Vol. 04.08, 232-237.

3.2 American Society for Testing and Materials (1991), *Standard Practice for Diamond Core Drilling for Site Investigation*, ASTM D:2113-83, Vol. 04.08, 260-263.

3.3 American Society for Testing and Materials (1991), *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, ASTM D:2488-90, Vol. 04.08, 320-329.

3.4 Environmental Protection Agency (1987), *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001.

3.5 Johnson, R. B., and J. V. DeGraff (1988), *Principles of Engineering Geology*, John Wiley and Sons, New York.

3.6 Terzaghi, K., and R. B. Peck (1967), *Soil Mechanics in Engineering Practice*, 2nd ed., John Wiley and Sons, New York.

3.7 U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control (1990), *NIOSH Pocket Guide to Chemical Hazards*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

4.0 DEFINITIONS

4.1 Dip

The maximum angle of inclination from the horizontal of bedding or other planar features. The angle is measured in a vertical plane perpendicular to the strike.

4.2 Flame Ionization Detector (FID)

A portable field instrument used for the quantification of organic compounds ranging from methane to aromatic compounds such as benzene. The FID works by ionizing molecules by a hydrogen flame, and measuring the current generated. The measured current is directly proportional to the number of ionized molecules, and so the concentration of the compound(s) can be determined. As the organic compounds burn, positively charged, carbon-containing ions are produced and are collected by a negatively charged collecting electrode. The current produced is directly proportional to the compound concentration. Due to the use of the flame, this instrument is less sensitive to moisture in the vapor stream than the photoionization detector. The FID is usually calibrated against methane, but can also be calibrated using other compounds.

4.3 Lithologic

Of, or pertaining to, the systematic description of geologic materials, in terms of mineral composition and texture.

4.4 Permeability

The ability of a sediment or rock to transmit ground water or other fluids through pores, cracks, and/or fractures.

4.5 Photoionization Detector (PID)

A portable field instrument used to quantify purgeable aromatic compounds such as benzene, toluene, and xylene in vapors, but is also useful for other organic compounds. It is most effective on unsaturated compounds containing double bonds. The PID works by directing UV light onto the molecules, ionizing them, and measuring the current generated. The measured current is directly proportional to the number of ionized molecules, so the concentration of the compound(s) can be determined. It is usually calibrated against isobutylene, but can be calibrated using a compound of interest such as trichloroethene (TCE). However, this devise is not compound specific and its measurements represent an aggregate concentration of all compounds that are ionized and

detected. Response factors can be changed to target specific compounds. This device is sensitive to moisture, therefore moist vapor streams should be analyzed using an alternate instrument such as an FID.

4.6 Strike

The angle between true North and the horizontal line contained in any planar feature (inclined bed, dike, fault plane, etc.); also the geographic direction of this horizontal line.

4.7 Turnaround Time

The time span between the submittal of samples to the analytical laboratory and the receipt of results.

5.0 RESPONSIBILITIES

Note: The following responsibilities (Sections 5.1–5.5) are listed by the appropriate level of authority to ensure that proper representation for all procedures and regulations related to this SOP are met.

5.1 Division Leader

The Division Leader's responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

5.2 Hydrogeologic Group Leader (HGL)

The HGL's responsibility is to ensure that proper procedures are followed for activities (i.e., drilling, borehole logging and sampling, monitor well installations and development) and to oversee the disposal of all investigation derived wastes.

5.3 Drilling Supervisor (DS)

The DS plans and coordinates all drilling related activities, ensures that all drilling related activities are performed safely and efficiently (using the proper procedures), and that the data generated from these activities are valuable and representative of the true geologic or physical conditions within the borehole. Such activities may include operation of logging equipment, soil sampling, well installation, and development. The DS is also responsible for:

5.3.1 Coordination of the drilling contractor schedules and equipment needs:

- Coordinate the schedules of multiple drill rigs with the drilling contractor.
- Provide the Work Plan to the drilling contractor and answer questions.
- Negotiate the arrival/start date and drill type.
- Monitor the progress of the drilling and anticipate changes in equipment needs (e.g., auger rig, air-mist rig, mud-rotary rig).

5.4 Drilling Coordinator (DC)

5.4.1 The DC provides the interface between the DS and the field activities including:

- Oversight of the Drilling Geologist (DG) and field activities.
- Coordinate the DG's work load.
- Obtain the necessary equipment, supplies, and release numbers from the Technical Release Representative (TRR) for the drilling contractor.
- Provide guidance and training.
- Inform the DG about procedural changes in areas related to drilling (e.g., changes in sampling requests, cuttings disposal issues, new forms, etc.).
- Provide technical input to the DG and Study Area Leader (SAL)/Facility Task Leader (FTL).
- Review borehole and geophysical logs.
- Monitor drilling progress on a daily basis.
- Interact with the Quality Assurance (QA)/Quality Control (QC) officer on drilling and soil sampling issues.
- Estimate the contaminants likely to be present, and the quantity of drilling spoils that may be generated.

5.4.2 During the startup of a new drilling phase, the DS works with the DC and SAL/FTL to:

- Create and finalize all related drilling documents (i.e., the Work Plan and Sampling Plan).
- Work with the SAL/FTL to establish drilling locations, schedules, and budgets for each well.
- Determine the protective equipment necessary for personnel in the field.
- Make well completion decisions and specify the well construction details from the SAL/FTL and Hydrogeologic Group Leader (HGL) input.
- Act as the liaison between the SAL/FTL and the DG.
- Coordinates all necessary biological/archeological surveys prior to drilling. Results of the surveys should be forwarded to the SAL/FTL and Environmental Chemistry and Biological Group Leader (ECBGL).

5.5 Drilling Geologist (DG)

The DG's responsibility is to ensure that drilling activities are carried out according to the specifications designated in the Work Plan, Sampling Plan, Site Safety Plan (SSP), Operation Safety Procedure (OSP), and Standard Operating Procedure (SOP). Additionally, the DG must oversee and document all aspects of the drilling/field investigation, including lithologic and geophysical data, well completion and development specifications, activities of the drillers, sampling and workspace monitoring details. The DG is also responsible for:

5.5.1 Site Preparation and Supply Ordering. The DG must:

- Review the Work Plan prepared by the SAL/FTL and DC, and discuss any questions.
- Assemble all necessary materials, including personal protective equipment (PPE).
- Supply tracking and ordering requests.
- Confirm that all necessary security arrangements have been made to permit site access (e.g., schedule escorts, notify the building coordinator of planned activities, arrange for opening of locked gates).
- Confirm that utility locator and mud pit excavations (if necessary) have been arranged with the field personnel.
- Discuss LLNL site planning requirements and utility lines with field personnel and drillers before drilling begins.

5.5.2 Site Safety

- Supply the SSP, OSP, and SOPs to all workers who enter the drill site.
- Monitor and record work space conditions with appropriate monitoring equipment (including FID, PID, etc.) during drilling activity.
- Confirm that appropriate fencing, warning signs, barricades, animal exit ramps (for mud pit), borehole cover and protection are in place.
- Discontinue work and contact the DC if chemical or physical hazards are encountered.

5.5.3 Field Activities

- Coordinate schedules/actions with field personnel.
- Research site hydrogeology to estimate key parameters (e.g., sample target zones, hydrostratigraphic unit depths and thicknesses, and types of contaminants).
- Obtain a field logbook from the Data Management Group (DMG).
- Calibrate and record calibration information for all monitoring equipment.
- Confirm all sample naming conventions with DMG.
- Collect and document samples.
- Handle all changes and corrections to chain-of-custody (CoC) forms and/or analytical requests.
- Inform the DC, SAL/FTLs, and DMG of any sampling or sampling documentation irregularities.
- Report any deviations from the SSPs, OSPs, or SOPs to the QA/QC Officer.
- If SOPs are violated, a nonconformance report is to be completed and submitted to the QA/QC officer.
- Report missed turnaround times for analytical sample results to QA/QC Officer.

- Confirm that drilling waste analytical results are consistent with the chosen disposal method.
- Decontaminate all sampling equipment.
- Provide frequent updates and documentation of field activities to the DC, HGL, and SAL/FTL.

5.6 Environmental Chemistry and Biology Group Leader (ECBGL)

The ECBGL's responsibility is to provide biological or chemical information and expertise (i.e., biological surveys, water supplies, chemical field instruments, etc.).

5.7 Field Personnel

The field personnel's responsibilities are to conduct all ERD field work that complies with all established operational and safety procedures, and to inform the HGL when the procedures are inappropriate.

Activities the field personnel are responsible to perform (but are not limited to) are to:

- Collect, store, and ship borehole samples to analytical laboratories.
- Drill, complete wells, log boreholes, and properly develop wells to allow the highest yield and the highest quality samples.
- Communicate the performance of development activities to the HGL and DC to allow for modification of the development methods to improve well yield.

5.8 Site Safety Officer (SSO)

The SSO's responsibility is to ensure the safety of ERD's ongoing operations and facilities and work performed. The SSO's responsibility is to receive the details of potential hazards and procedures for all field activities. The SSO directs this information to the LLNL Hazards Control Department to determine if a new Operational Safety Procedure (OSP) is required, thus assuring that an existing OSP addresses all ES&H issues for each operation.

5.9 Study Area Leaders (SAL)/Facility Task Leader (FTL)

The SAL/FTL are responsible for the overall investigation, planning, assessment, and remediation within a study area.

5.10 Technical Release Representative (TRR)

The TRR is responsible for the acquisition and administration of blanket contract releases for the procurement of goods and services. The TRR has the authority to obligate LLNL for payment of goods and services, delegated by the LLNL Business Manager through the LLNL Procurement Department.

5.11 Treatment Facility Hydrogeologist (TFH)

The TFH is responsible for helping the SAL/FTL determine borehole location and target zone for completion.

6.0 PROCEDURES

6.1 Office Preparation

6.1.1 The DC must provide the TRR with an estimate of sampling requirements prior to obtaining a release number.

6.1.2 The DG should obtain materials listed in the Equipment Checklist (Attachment A) and obtain the appropriate PPE (SOP 4.1, "General Instructions for Field Personnel").

6.1.3 The SAL/FTL and DC should gather site hydrogeology data to estimate key parameters (e.g., sample target zones, depth and thickness, types of contaminants, etc.).

6.1.4 The DC should coordinate schedules/actions with the DG and SAL/FTL. For Livermore Site activities, Site Planning should be notified at least 2 weeks prior to drilling activities. In addition, boreholes that are drilled near buildings should be cleared with the Building Coordinator.

6.1.5 The DG should obtain a Field Sampling Logbook to record sample numbers and CoC document numbers (SOP 4.2, "Sample Control and Documentation").

6.1.6 The DG should review pertinent sections of the SSP, and obtain appropriate documentation that the proposed borehole location is clear of underground utilities .

6.1.7 The DC will ensure that expected conditions that will be encountered are included in the appropriate OSP. Any expected or suspected conditions either of a chemical or physical nature, which are not included in the OSP necessitate the production of an OSP addendum to address these issues.

6.1.8 The DG shall obtain a field protocol as prepared by the DC or SAL/FTL. The protocol should contain the following borehole information:

A. Number(s).

B. Location.

C. Purpose.

D. Estimated depth(s).

E. Estimated depth of conductor casing(s).

F. Drilling method.

G. Lithologic sampling.

H. Logging intervals.

I. Chemical and sample intervals.

J. Analysis and required turnaround time.

6.2 Field Preparation

6.2.1 Obtain necessary items to label all samples. Record CoC document numbers and soil sample numbers per SOP 4.2.

6.2.2 Decontaminate all sampling equipment prior to sampling a new borehole and/or the next sample interval within the same borehole per SOP 4.5, "General Equipment Decontamination."

6.2.3 Follow SOP 4.4, "Guide to the Handling, Packaging, and Shipping of Samples."

6.2.4 Follow the instructions pertaining to conducting field work per SOP 4.1.

6.2.5 New DGs will receive direct field supervision during borehole logging from an experienced supervisor for at least the first three logging days .

6.2.6 Regularly monitor drill cuttings and work area with a PID or FID. If the readings exceed the time-weighted average (TWA) values, or exceed half of the threshold limit values (TLV) for known or suspected chemicals, or breathing zone concentrations recorded by the field monitoring exceed twice background concentrations, or in the absence of background concentrations 5 ppm, cease the operations and contact the DS, HGL, or DC, who will notify the Environmental Safety and Health (ES&H), Operational Safety Division, and LLNL Hazards Control Department (see Attachment B for selected contaminant exposure limits).

The DG shall cease drilling operations and contact the DC when:

1. Breathing zone concentrations recorded by the field monitoring exceed twice background concentrations,

2. 5 ppm is measured with an FID or PID, or

3. There is evidence of contamination that could impact worker health and safety.

The DC shall then contact the DS who will notify the appropriate technical support personnel from the ES&H team.

6.3 Operation

6.3.1 Document the borehole location, drilling and sampling methods, and administrative data on the first page of the Borehole/Well Construction Log (Attachment C) as described below:

1. **Borehole Location**. Prepare a map showing borehole location with respect to permanent natural and man-made features and any existing nearby wells. When feasible, record distance to at least two permanent locations or one location when directional (i.e., compass bearing) data are provided. Show a north arrow preferably oriented toward the top of the page.

2. **Project**. Identify the project as Lawrence Livermore National Laboratory (LLNL) Site 300 or Livermore Site. In addition, include the general area in which the borehole is located (e.g., off site, Building 834, T-5475).

3. **Borehole/Well Number**. The borehole/well number as provided by the field protocol.

4. **Release Number**. Release number as provided by the HGL/DC.

5. **Logged By**. Identifies the individual(s) responsible for logging the borehole, performing field measurements, and collecting samples.

6. **Edited By**. Identifies the geologist who independently reviews and checks the boring/well log entries.

7. **Project Manager**. Identifies the DS.

8. **Drill Rig**. Identifies drill rig manufacturer and model.

9. **Drilling Contractor**. Identifies the drilling company and its city of origin.

10. **Driller/Helper**. Identifies drill rig operator and helper(s).

11. **Drilling Method**. Identifies the method(s) used to drill the borehole.

12. **Sampling Method**. Identifies the method(s) used to collect lithologic and chemical samples.

13. **Hammer Weight/Drop**. The drive sampler hammer weight in pounds and drop distance in inches for the hammer used to advance drive samplers.

14. **Borehole Diameter**. Diameter of final borehole in inches and tenths of an inch. Also note diameter of any pilot boreholes drilled.

15. **Borehole Started Time/Date**. Identifies time (24 h) and date when drilling began.

16. **Water Introduced into Borehole/Well.** Indicates whether or not water was introduced into the borehole during drilling and/or into the well during development. If so, identifies the source (e.g., fire hydrant location, faucet, and number).

17. **Bentonite Gel Used.** Indicate whether or not bentonite gel was used as a drilling fluid. If so, identify the product name and manufacturer. No polymer-bearing drilling fluid additives shall be used unless approved in advance by the ECBGL.

18. **Borehole Completed Time/Date**. Identifies time (24 h) and date when borehole or well was grouted to surface.

19. **Well Construction Started Time/Date.** Identifies the time (24 h) and date when well construction begins.

20. **Well Construction Completion Time/Date.** Identifies time (24 h) and date when well installation is complete.

21. **Well Head Completion.** Identifies the type of well head completion (e.g., locking 9-in. diameter galvanized steel pipe [“stove pipe”] or Christy box).

22. **Depth to Water**. Water levels in boreholes should be recorded when water is first encountered during drilling and then at least once after drilling has been completed or a piezometer and/or monitor well has been installed.

Before taking water level measurements, review SOP 3.1, "Water Level Measurement." Include borehole/casing depth, water depth, time, and date using ground surface as the datum.

23. **Total Depth.** Record total depth of borehole in feet.

24. **Casing Depth**. Record total depth of well casing and screen in feet.

25. **Screened Interval**. Include depth interval of perforated casing in feet.

26. **Sandpack**. List depth interval of filter pack in feet. Include manufacturer name and designation of sand.

27. **Well Development.** Identifies the method(s), and time (24 h), date, and estimated flow rate in gallons per minute (gpm) when well development was completed.

28. **Geophysical Logs**. Identify geophysical logging company, method(s), and date. If geophysical logging is not performed during initial drilling and well installation, enter NA (not applicable).

29. **Circulation**. Volume of fluid losses and the interval over which they occur. When the column is left blank, it indicates that no fluid loss was observed. Complete fluid loss (CL) means that no fluid returned to the surface during pumping. If possible, give quantitative estimates of major fluid losses (rate: in gpm, or estimate of total gallons lost). Although the above mentioned circulation loss applies primarily to air and mud rotary systems, it can also be used during auger drilling to indicate quantity of return of cuttings at the surface.

30. **Notes**. List chronological drilling and reaming information. Record any abbreviations used or additional information relevant to borehole logging and sampling.

6.3.2 Documentation of Sampling

A. **Sampler Type/Depth**. Give sampler type by the letter code listed below.

Sampler type	Inside diameter (in.)	Code
Standard penetrometer	**1.38**	**SP**
Split-barrel (small)	**2.0**	**SBS**
Split-barrel (large)	**2.5**	**SBL**
HQ wireline core	**2.3**	**PC**

B. Depth at the top of the sampling interval is given in feet.

C. **Blows/6-in**. The number of blows required to drive the sampler 6 in. by a 140-lb hammer falling 30 in. Fifty blow counts per 6-in drive is considered "refusal," and sampling at this depth is usually terminated. In addition, a total of 100 blow counts per 18-in. drive, or no observed advance of the sampler during ten successive hammer blows, is also considered "refusal." During coring, enter NA (not applicable). Normally, the second and third 6 in. intervals are recorded and added as the number of blows per feet.

D. **Inches Driven.** The distance in inches the sampler is advanced.

E. **Inches Recovered**. The length in inches of sediment or rock recovered on a sampling or core run. A recovery ratio for 10 in. of recovery on a 18-in. sampling interval for a core run would be: $\frac{10}{18}$.

F. **Sample Condition/Rock Quality Designation (RQD)**. Indicates the estimated quality of the sample for analysis: P = poor, F = fair, G = good, E = excellent. When rock coring, the RQD is reported in the unreduced fraction form. The numerator is the length in inches of intact core 4 inches or greater in length, and the denominator is the length of the core run in inches.

G. **Recovery/Sample Location**. Sample recovery is shown graphically by an "×" in the recovery column on the log. The location of a sample collected for further evaluation is shown by a solid box. When partial sample loss occurs, it is often possible to determine why and where core loss has occurred. For example:

1. Rock stuck in drive shoe.
2. Coring from dense (stiff) material to soft material causing block-off.
3. Loss of cohesionless material.
4. Fell out during retrieval of core sampler.
5. Mechanical failures.

Note: If uncertain where sample loss has occurred, recovered interval is assumed to be from the top of the sampling interval.

H. **Sample Identification (ID)**. Depth at the top of the sampling interval is given in feet and tenths of feet. The sample designation distinguishes between unsaturated samples (B-#-depth-u) and saturated samples (B-#-depth-s).

I. **Analysis**. Identifies laboratory analysis to be performed on sample.

6.3.3 Geologic Documentation

A. **Contact**. Lithologic contacts are drawn in the contact column when possible. If the contact is identified by the driller, specify this on the Borehole/Well Construction Log. Three types of contacts are used:

1. **Sharp**. A sharp contact is indicated with a solid line.
2. **Gradational**. A gradational contact is indicated with hatches.
3. **Approximate**. An approximate contact is indicated by a dashed line and is used when the exact depth or nature of the lithologic contact is uncertain.

B. **Lithologic Description**. A continuous log of encountered geologic materials determined from borehole cuttings, samples, and core should be recorded on the Borehole/Well Construction Log. A system of description similar to the American Society for Testing and Materials (ASTM) method D 2488-90

(1991), *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure), is used for sediment, and a similar description is used for rock. Lithologic descriptions record direct field observations. Any interpretations included with these descriptions should be clearly noted by placing the interpretation in parentheses. The format is outlined below:

1. Fine-Grained Sediment Description Format.

    a. Contact depth in feet and tenths of a foot.

    b. **Textural Classification**. The appropriate classification as listed in Attachment D.

    c. **Group Symbol**. The appropriate sediment group symbol as listed in Attachment E.

    d. **Color**. Soil color is named and coded using the Munsell Soil Color chart. Presence of mottling and banding is also recorded.

    e. **Consistency/Penetration Resistance**. For fine sediments use very soft, soft, medium, stiff, very stiff, and hard. These are estimated from drive sample hammer blows or other field tests. Blow counts may also be used, if reliable.

    f. **Moisture Content.** Dry, damp, moist, wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.

    g. **Size Distribution**. Approximate percentage of gravel, sand, fines (if possible, distinguish between silt and clay).

    h. **Estimated Permeability**. Very low, low, moderate, or high. These are based primarily on grain size and sorting.

    i. **Miscellaneous**. Odor, contact and/or bedding dip, cementation, structures, fractures, fracture fillings, fossils, formation name, etc.

2. Coarse-Grained Sediment Description Format.

    a. Contact depth in feet and tenths of a foot.

    b. **Textural Classification**. The appropriate textural classification as listed in Attachment D.

    c. **Group Symbol**. The appropriate sediment group symbol as listed in Table Attachment E.

    d. **Color**. Presence of mottling and banding, as well as Munsell soil color name and code.

    e. **Relative Density/Penetration Resistance.** For cohesionless materials use very loose, loose, medium, dense, or very dense estimated from drive sample hammer blows or other field tests. Blow counts may be used, if reliable.

    f. **Moisture Content.** Dry, damp, moist, and wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.

g. **Size Distribution**. Approximate percentage of gravel, sand, and fines (silt and clay).

h. **Grain Shape**. Angular, subangular, subrounded, rounded, or well-rounded, for grains larger than sand size.

i. **Grain Size**. The largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.

j. **Estimated Permeability**. Very low, low, moderate, or high. This is based primarily on grain size and sorting.

k. **Miscellaneous**. Odor, contact and/or bedding dip, sorting, structures, fossils, cementation, geologic origin, formation name, etc.

3. Fine-Grained Rock Description Format.

a. Contact depth in feet and tenths of a foot.

b. **Textural Classification**. The appropriate classification as listed in Attachment D.

c. **Color**. Presence of mottling and banding, as well as rock color name and code. The Geological Society of America rock color chart is recommended, if available.

d. **Hardness**. The appropriate descriptive term for hardness as found in Attachment G.

e. **Moisture Content**. Dry, damp, moist, wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.

f. **Size Distribution**. Approximate percentage of gravel, sand, and fines (silt and clay).

g. **Estimated Permeability**. Very low, low, moderate, or high. This is based primarily on grain size, sorting, and cementation. Estimate secondary permeability due to natural rock fractures when applicable.

h. **Miscellaneous**. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.

i. Fractures are identified by depth, angle, width, and associated mineralization if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]) should follow in parentheses.

4. Coarse-Grained Rock Description Format

a. Contact depth in feet and tenths of a foot.

b. **Textural Classification**. The appropriate classification as listed in Attachment D.

c. **Color**. Presence of mottling and banding, as well as rock color name and code. The Geological Society of America rock color chart is recommended, if available.

d. **Hardness**. The appropriate descriptive term for hardness as found in Attachment G.

e. **Moisture Content**. Dry, damp, moist, and wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.

f. **Size Distribution**. Approximate percentage of gravel, sand, and fines (silt and clay).

g. **Grain Shape**. Angular, subangular, subrounded, rounded, or well-rounded, for grains larger than sand size.

h. **Grain Size**. The largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.

i. **Estimated Permeability**. Very low, low, moderate, or high. This is based primarily on grain size, sorting, and cementation. When applicable, estimate secondary permeability due to natural rock fractures.

j. **Miscellaneous**. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.

k. Fractures are identified by depth, angle, width, and associated mineralization, if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]), should follow in parentheses.

6.3.4 General Abbreviations Used for Lithologic Descriptions

PC = punch core
RC = rock core
v = very
f = fine
m or med. = medium
mod = moderate
c = coarse
min = mineralization
w/ = with
SA = subangular
SR = subrounded
R = rounded
A = angular
soft sed def'm = soft sediment deformation
DF = drilling fluid (mud)
x-beds = cross beds
@ = at
RQD = rock quality description
ppm = parts per million
rx w/HCI = reaction with hydrochloric acid
FeOx= iron oxide
MnO_2 = manganese oxide
P = plasticity

6.3.5 Conductivity Estimates

1st K = primary conductivity
2nd K = secondary conductivity due to fracturing, mineralization, etc.
HEK = high estimated conductivity
MEK = moderate estimated conductivity
LEK = low estimated conductivity
VLEK = very low estimated conductivity

6.3.6 Fractures

6.3.6.1 Core fractures are described as follows:

(Depth/fracture type (see below)/angle w/mineralization or other characteristics)

CIF = coring induced fracture
HIF = handling induced fracture
NF = natural fracture

6.3.7 Notes

- All fractures are open unless specified as "closed."
- If not specified in description, conductivity designation describes primary conductivity.
- Work space and core samples were regularly screened using a PID/FID.
- All Munsell colors recorded describe color while the core is wet, unless otherwise specified.
- Moisture content descriptions (when provided) are inferred due to the nature of mud rotary drilling.

6.4.4 Logging Methods

A. Auger Drilling

1. Observe cuttings and note drill rig behavior.
2. Collect split-barrel sample or continuous core as directed in the field protocol.

B. Wireline Coring

1. Attempt continuous coring if possible.
2. Observe drill cutting composition, mud/water or cutting color changes, fluid pressure, and rig behavior when there is potential partial core recovery.

C. Rotary Drilling

1. Observe cuttings, note drill rig behavior, fluid pressure, and mud or water color changes. Obtain input from driller if uncertain about lithology intervals.
2. Collect split-barrel or punch core as directed in the field protocol.

6.5 Field Post Operation

6.5.1 Store recovered sediment and rock core in core boxes using a black indelible pen to mark sample intervals/runs. Label each box with the project ID, borehole number, depth interval, and box number, and store per instructions by DS or DC**.**

6.5.2 Place temporary protective cover, as appropriate, over borehole.

6.5.3 Collect all samples, inventory, and prepare samples for shipment per SOP 4.4, "Guide to the Handling, Packaging, and Shipping of Samples" and SOP 4.2.

6.5.4 Decontaminate all equipment as noted in SOP 4.5.

6.5.5 Make sure all boreholes are properly marked and that proper borehole ID is readily visible to allow survey team to locate and survey borehole location.

6.5.6 Record daily summary of drilling and sampling in the Field Sampling Logbook per SOP 4.2.

6.6 Office Post Operation

Deliver original copies of Borehole/Well Construction Log, Well Development Form, Field Logbook, and all other relevant forms and information to the DC for review, filing, and distribution.

7.0 QUALITY ASSURANCE RECORDS

7.1 Borehole/Well Construction Log

7.2 Field Logbook

8.0 ATTACHMENTS

Attachment A—Equipment Check List

Attachment B—Exposure Limits for Selected Contaminants (Table B-1)

Attachment C—Borehole/Well Construction Log

Attachment D—Textural Classifications (Table D-1)

Attachment E—Sediment Group Symbols (Table E-1)

Attachment F—Moisture Classifications (Table F-1)

Attachment G—Rock Hardness Classifications (Table G-1)

Attachment A

Equipment Checklist

Equipment Checklist

_____ Aluminum foil
_____ Any applicable permits
_____ Appropriate clothing (i.e., coveralls, steel-toed safety shoes, and gloves)
_____ Appropriate documentation (i.e., Sampling Plan, OSP, SOP, SSP, etc.)
_____ Bailers (Teflon or stainless steel)
_____ Bailer cord
_____ Barricades
_____ Brunton compass if needed
_____ Buckets and brushes
_____ Caution Tape
_____ Company ID sign for vehicle (if applicable)
_____ Cooler with ice
_____ Core boxes and trays, black indelible marking pens
_____ Deionized water
_____ Detergents (Alconox, TSP)
_____ Document control logbook
_____ Drums
_____ Duct tape
_____ Field forms (i.e., CoC forms and Borehole/Well Constructions forms, etc.)
_____ Field notebook
_____ Fire extinguisher
_____ First aid kit
_____ Glass jars
_____ Hard hat
_____ Hearing protection
_____ Measuring wheel
_____ Munsell soil color chart
_____ Rock hammer
_____ PID or FID
_____ Safety glasses
_____ Sample containers/labels
_____ Sampling gloves (vinyl, latex or nytrile, as appropriate)
_____ Signs listing responsible persons (if applicable)
_____ Soil sample tubes
_____ Steel measuring tape with engineering scale
_____ Protractor
_____ Steel spatula
_____ Teflon tape (4 in. width)
_____ Water-level meter
_____ 300-ft weighted tape

Attachment B

Exposure Limits for Selected Contaminants

Table B-1. **Exposure limits for selected contaminants.**

Chemical name	Exposure limits (TWA[a])	IDLH[b]
Arsenic	**0.002 mg/m^3[c] [15 min]**	**100 mg/m^3**
Barium	**0.5 mg/m^3**	**1,100 mg/m^3**
Benzene	**0.1 ppm**	**3,000 ppm**
	1 ppm[d]	
Freon 113	**1000 ppm**	**4,500 ppm**
	(7600 mg/m^3)	
	1250 ppm[d]	
	(9500 mg/m^3)	
Tetrachloroethylene	**25 ppm**	**500 ppm**
Toluene	**100 ppm**	**2,000 ppm**
	(375 mg/m^3)	
	150 ppm[d]	
	(560 mg/m^3)	
Trichloroethylene	**25 ppm**	**1,000 ppm**
Uranium	**0.2 mg/m^3**	**30 mg/m^3**
	0.6 mg/m^3[d]	

a **Time-weighted average (TWA) concentrations for up to a 10-h workday during a 40-h workweek, unless noted otherwise.**

b **Immediately Dangerous to Life or Health concentrations.**

c **Indicates a ceiling value which should not be exceeded at any time.**

d **Short-term exposure limit is a 15-min TWA exposure that should not be exceeded at any time during a workday.**

Note: See reference 3.7 for more information.

Attachment C

Borehole/Well Construction Log

WEISS ASSOCIATES

BOREHOLE / WELL CONSTRUCTION LOG

Page ____ of ____

BOREHOLE LOCATION	Project:	Borehole / Well No:
		Job No:
	Logged By:	Edited By:
	Project Manager:	Drill Rig:
	Drilling Contractor:	
	Driller / Helper:	
	Drilling Method:	Sample Method:
	Hammer Weight / Drop:	Bentonite / Gel Product Used:
	Borehole Diameter, Pilot:	Final:
	Borehole Started, Time / Date:	Borehole Completed, Time / Date:
	Well Started, Time / Date:	Well Completed, Time / Date:
Notes:	Water Depth	
	Boring / Casing Depth	
	Time	
	Date	

OVA / PID Field Readings (ppm)																
Work Area	Soil / Rock	Sampler Type / Depth	Blows / 6 Inches for RQD	Inches Driven / Inches Recovered	Sample Condition / Time	Sample ID / Depth: _____ Depth F	Analysis	Outer Annulus	Conductor Casing(s)	Well Annulus / Borehole Filler	Well Casing	Depth in Feet	Recovery / Sample Loc.	Contact	LITHOLOGIC DESCRIPTIONS	
												1				
												2				
												3				
												4				
												5				
												6				
												7				
												8				
												9				
												10				

Total Depth: | Casing Depth:

Screened Interval:

Sand Pack, #3: | #0:

Well Development Method:

Time: | Date: | Flow Rate:

Geophysical Logs, Type:

By: | Date:

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Attachment C. Borehole/Well Construction Log.

WEISS ASSOCIATES

BOREHOLE / WELL CONSTRUCTION LOG (cont.) Page ____ of ____

OVA/PID Field Readings (ppm)																
Work Area	Soil/Rock	Sampler Type/Depth	Blows / 6 Inches for RQD	Inches Driven/ Inches Recovered	Sample Condition / Time	Sample ID/Depth: ____ Depth F	Analysis	Outer Annulus	Conductor Casing(s)	Well Annulus/ Borehole Filler	Well Casing	Depth in Feet	Recovery / Sample Loc.	Contact	Project / Job No.:	Borehole/Well No.:
															Notes:	
												1				
												2				
												3				
												4				
												5				
												6				
												7				
												8				
												9				
												0				
												1				
												2				
												3				
												4				
												5				
												6				
												7				
												8				
												9				
												0				

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Attachment C (Continued).

Attachment D

Textural Classifications

Attachment D-1. Textural classifications for the Livermore Site and Site 300.

Type	Classification
Sediment:	
Fine grained	**Gravelly silt, sandy silt, silt, clayey silt, sandy clay, silty clay, clay, organic silt, and organic clay.**
Coarse grained	**Sand, clayey sand, silty sand, gravelly sand, gravel, clayey gravel, silty gravel, and sandy gravel.**
Rock:	
Fine grained	**Sandy siltstone, siltstone, clayey siltstone, sandy claystone, silty claystone, claystone.**
Coarse grained	**Sandstone, clayey sandstone, silty sandstone, gravelly sandstone, conglomerate, clayey conglomerate, silty conglomerate, and sandy conglomerate.**

Attachment E

Sediment Group Symbols

Attachment E-1. Sediment group symbols.

Fine-grained		Coarse-grained	
Group symbol	Group name	Group symbol	Group name
CL	Low to medium plasticity clays	GW	Well-graded gravel
ML	Nonplastic to medium plasticity silt	GP	Poorly graded gravel
OL	Organic clay or silt (lean)	GM	Silty gravel
CH	High plasticity clays	GC	Clayey gravel
MH	High plasticity silt	SW	Well-graded sand
OH	Organic clay or silt (fat)	SP	Poorly graded sand
PT	Peat	SM	Silty sand
		SC	Clayey sand

Attachment F

Moisture Classifications

Attachment F-1. Moisture classification.

Moisture term	Description
Dry	Absence of moisture to the touch.
Damp	Contains enough water to keep the sample from being brittle, dusty or cohesionless; is darker in color than the same material in the dry state.
Moist	Leaves moisture on your hand, but displays no visible free water.
Wet	Displays visible free water.

Attachment G

Rock Hardness Classification

Attachment G-1. Rock hardness and classifications.

Descriptive term	Defining characteristics
Very hard	Cannot be scratched with knife; does not leave a groove on the rock surface when scratched.
Hard	Difficult to scratch with knife; leaves a faint groove with sharp edges.
Medium	Can be scratched with knife; leaves a well-defined groove with sharp edges.
Soft	Easily scratched with knife; leaves a deep groove with broken edges.
Very soft	Can be scratched with a fingernail.